



Available online at

ScienceDirect
www.sciencedirect.com

Elsevier Masson France

EM|consulte
www.em-consulte.com/en



CLINICAL RESEARCH

Safety and efficiency of the new micro-multiplane transoesophageal probe in paediatric cardiology



Nouvelle sonde micro transœsophagienne en cardiologie pédiatrique

Sébastien Hascoët^{a,1}, Marianne Peyre^{a,1},
Khaled Hadeed^a, Xavier Alacoque^b,
Gérald Chausseray^b, Rose Fesseau^b,
Romain Amadiou^a, Bertrand Léobon^c,
Lionel Berthomieu^d, Yves Dulac^a, Philippe Acar^{a,*}

^a Paediatric Cardiology Unit, Children Hospital, Toulouse University Hospital, 330, avenue de Grande-Bretagne, 31059 Toulouse cedex 9, France

^b Department of Anesthesiology, Children Hospital, Toulouse University Hospital, 31059 Toulouse cedex 9, France

^c Department of Congenital Heart Disease Surgery, Children Hospital, Toulouse University Hospital, 31059 Toulouse cedex 9, France

^d Department of Paediatric Intensive Care Unit, Children Hospital, Toulouse University Hospital, 31059 Toulouse cedex 9, France

Received 21 March 2014; received in revised form 28 April 2014; accepted 6 May 2014
Available online 1 July 2014

KEYWORDS

Transoesophageal echocardiography;
Congenital heart disease;

Summary

Background. — Transoesophageal echocardiography (TOE) is feasible in neonates using a miniaturized probe, but is not widely used because of low imaging quality.

Aims. — To assess handling and imaging quality of a new release of a micro-TOE probe in children.

Methods. — Thirty-eight consecutive children, enrolled during February and May 2013, underwent TOE with the Philips S8-3t probe. Insertion, handling and image quality were assessed.

Abbreviations: CHD, congenital heart disease; ECMO, extracorporeal membrane oxygenation; ICU, intensive care unit; TOE, transoesophageal echocardiography.

* Corresponding author.

E-mail address: acar.p@chu-toulouse.fr (P. Acar).

¹ Sébastien Hascoët and Marianne Peyre contributed equally to this work.

<http://dx.doi.org/10.1016/j.acvd.2014.05.001>

1875-2136/© 2014 Published by Elsevier Masson SAS.

Paediatric cardiology;
Neonates;
Children

Results. — The 38 children (aged 7 days to 12 years; weight 3.1–27 kg) underwent 75 TOE (30 [40.0%] before cardiac surgery, 31 [41.3%] after cardiac surgery, 4 [5.3%] during a percutaneous procedure, 10 [13.3%] in the intensive care unit). Insertion of the micro-TOE probe was 'very easy' in 37/38 patients (97.4%). Handling was better in the lightest children ($P=0.001$). Image quality was mainly 'good' or 'very good', with no significant changes between preoperative and postoperative examinations or over time. Total scores (insertion, handling, image quality) were significantly better in the lightest children ($P=0.02$). Preoperative TOE did not provide additional information over transthoracic echocardiography. Postoperative TOE was useful to assess surgical results, but no residual lesions required extracorporeal circulation return. Micro-TOE was useful during the postoperative care of neonatal surgery with open breastbone to assess the surgical result and ventricular function. It was also useful to guide extracorporeal membrane oxygenation (ECMO) indication and withdrawal; and was a useful guide for percutaneous procedures.

Conclusion. — Micro-multiplane TOE is safe and efficient for use in neonates and children. This minimally invasive tool increases the impact of TOE in paediatric cardiology.

© 2014 Published by Elsevier Masson SAS.

MOTS CLÉS

Échographie
transœsophagienne ;
Cardiopathie
congénitale ;
Nouveau-nés ;
Micro-multiplan ETO ;
Enfants

Résumé

Contexte. — L'échographie transœsophagienne (ETO) est réalisable chez le nourrisson à l'aide de sondes miniaturisées dédiées. Néanmoins, l'usage n'est pas répandu du fait d'une qualité d'image moyenne.

Objectif. — Nous avons évalué la maniabilité et la qualité d'image de la nouvelle version de la sonde transœsophagienne micromultiplan S8-3t durant la pratique courante en cardiopédiatrie.

Méthodes. — Trente-huit enfants ont été inclus consécutivement entre février et mai 2013 avec réalisation d'une ETO avec la sonde Philips S8-3t. La maniabilité et la qualité d'image ont été évaluées indépendamment par deux opérateurs.

Résultats. — Soixante-quinze ETO avec la sonde micro S8-3t ont été réalisées chez les 38 enfants, âgés de 7 jours à 12 ans (3–27 kg). Les indications étaient requises par l'usage courant : au bloc opératoire avant ($n=30$, 40,0%) ou après ($n=31$, 41,3%) une chirurgie cardiaque, pour guider des procédures de cathétérisme interventionnelles ($n=4$, 5,3%) et en réanimation pédiatrique ($n=10$, 13,3%). L'insertion a été simple chez tous les patients sauf un (2,6%). La maniabilité et la stabilité de la sonde étaient meilleures chez les enfants les plus légers ($p=0,001$). La qualité d'image était bonne et globalement meilleure chez les enfants de faible poids. Il n'a pas été constaté de détérioration de la qualité d'image entre avant et après la chirurgie cardiaque ni durant l'étude. L'ETO préopératoire n'a pas apporté d'informations complémentaires par rapport à l'échographie transthoracique préopératoire. L'ETO postopératoire a permis d'apprécier le résultat chirurgical mais aucune lésion n'a nécessité un retour en circulation extracorporelle. La sonde micro S8-3t s'est révélée très utile pour la gestion postopératoire de chirurgie cardiaque néonatale avec thorax ouvert et pour guider l'indication et le retrait d'assistance circulatoire transitoire. L'ETO micro s'est révélée utile pour le guidage de cathétérisme interventionnel pédiatrique.

Conclusion. — L'ETO avec la sonde micro S8-3t est un examen utile, sûr et efficace au bloc opératoire de chirurgie cardiaque pédiatrique, en salle de cathétérisme et en réanimation pédiatrique. Cette sonde micro peu invasive augmente l'intérêt de l'ETO en cardiologie pédiatrique, particulièrement chez le nouveau-né et le nourrisson.

© 2014 Publié par Elsevier Masson SAS.

Background

Transoesophageal echocardiography (TOE) is a useful tool for the surgical or interventional treatment of congenital heart disease (CHD) in children and neonates [1–7]. It is also useful for the assessment of cardiac function and haemodynamic status in the intensive care unit (ICU) [8,9]. The first reports assessing TOE were published in the 1990s, but these were in older children and adults. Many surgeries for CHD are

performed in neonates, raising difficulties of insertion and risk of complications (e.g. oropharyngeal and oesophageal traumas, arrhythmias and circulatory disturbance [1,7]) with mini-multiplane probes.

In 2007, a micro-multiplane probe was released for use in neonates. Handling was good, but image quality was low, possibly due to an overheating issue [10]. In the current study, we tested a new release of the micro-multiplane probe and report our initial experience of clinical use. The

primary objective was to assess the imaging quality of this new probe in current practice in children undergoing cardiac surgery, catheterizations and in the ICU. Secondary objectives were to assess safety and handling.

Methods

Patients

Between February and May 2013, consecutive children were enrolled prospectively from the paediatric cardiology unit of the children's hospital of Toulouse. Children for whom a TOE was indicated for a medical purpose (cardiac surgery, an interventional procedure or in the ICU) during the study period were enrolled. Exclusion criteria were: lack of consent, accurate transthoracic echocardiographic images in the ICU obviating the need for a TOE examination and contraindications for TOE as stated in the recommendations from the Pediatric Council of the American Society of Echocardiography [1].

Informed verbal consent was obtained from each patient (when possible) and their legal representatives after full explanation of the procedure had been given. Written consent was not required according to French laws because the echography evaluation was part of the regular management of these children and was required for their medical condition. No additional examinations were performed solely for the purpose of the study. The study protocol was approved by the national commission for data processing and freedoms (N° 1673449v0: declared on 31st May 2013).

Micro-TOE S8-3t probe

The new release of the S8-3t probe (Philips Healthcare Medical Systems, Andover, MA, USA) was used in all cases. It has been available for clinical use since 2012. It has a tip length of 18.5 mm, a tip width of 7.5 mm, a tip height of 5.5 mm and a shaft diameter of 5.2 mm. The transducer array is mounted on a pulley, providing various angle views ranging from 0° to 180° from a median longitudinal cross-sectional view. The probe can anteflex up to 110° and retroflex up to 45°. The first enhancement is an improved mechanism for sensor rotation. New 7 × 7 steering cables are stronger, more flexible and less susceptible to failure with use. The second improvement is a new articulation knob that is easier to control. The probe allows two-dimensionnal colour imaging with pulsed and continuous Doppler in children weighing < 4.5 kg. The micro-multiplane TOE probe S8-3t was used with the iE33 ultrasound machine (Philips Medical Systems).

Micro-TOE probe insertion

The micro-TOE probe was systematically inserted after patient sedation and intubation, before surgery or catheterization. In the ICU, the micro-TOE was used in patients under mechanical ventilation when transthoracic echocardiography was not feasible (open breastbone). The previously lubricated probe was inserted blindly and delicately with a jaw thrust of the mandible or, if not feasible, under

direct visualization by laryngoscopy. After the initial examination during CHD surgeries, the probe was advanced into the stomach and left in an unlocked position during the procedure. The ultrasound machine was turned off during surgery. During the weaning from extracorporeal circulation, the post-repair TOE examination was performed.

TOE image acquisition and scoring system

For congenital heart disease surgery, two TOE examinations were performed: one before surgery to confirm or modify the other preoperative examinations and one after surgery. Relevant modifications of the preoperative diagnosis from the TOE findings were to have been displayed and discussed with the surgical team.

Examinations were performed by one of two first operators (S. H. or M. P.). For each patient, the following recommended views were performed: mid oesophageal four chamber (0–20°), right ventricular outflow tract (60–90°), left outflow tract and aortic valve (short axis 30–60°, long axis 100–150°), mitral commissural (60–70°) and trans-gastric views [1]. Off-line analysis was performed by a second operator (K.H.) to assess inter-rater agreement of the imaging quality scoring.

Ease of use (insertion and handling) was scored by the first operator. Imaging quality (two-dimensionnal echocardiography, colour Doppler, pulsed Doppler and continuous Doppler) was scored by the first and second operators. The scoring system is described in Table 1. The total score was calculated for each child by the sum of the scores of the six criteria.

Side effect evaluation

Particular attention was paid to haemodynamic parameters during probe insertion and TOE examination. After the TOE, the probe and oropharynx were inspected for any sign of blood or trauma. No specific medications, e.g. proton pump inhibitors, were routinely given.

Statistical analysis

Age and weight are expressed as median (range); qualitative data are expressed as number and percentage. For CHD surgeries, imaging quality between the preoperative and the postoperative examinations was compared. As we did not find any difference in scoring between repeated TOEs within the same child, we also performed a per-patient analysis. We investigated the impact of the weight (as a continuous variable) on the ratings for each of the six criteria using the non-parametric Kruskal-Wallis test. Patients were stratified in four groups according to quartiles of weight. Comparisons of ratings of the six criteria (Table 1) between the four weight groups were performed using a non-parametric exact Fischer test. The total score was compared between the four groups using the Kruskal-Wallis test. Inter-rater agreement between the two operators was assessed using the kappa coefficient for quality of imaging (criteria 3–6 in Table 1). A *P*-value < 0.05 was considered statistically significant. Statistical analysis was performed using Stata8 (Statacorp, TE, USA).

Table 1 Scoring system.

Category	Criteria	Score			
		1	2	3	4
Ease of use	1. Probe insertion	Very easy (insertion blindly or under laryngoscopy within 1 minute)	Easy (under laryngoscopy within 2 minutes)	Hard (insertion under laryngoscopy requiring > 2 minutes)	Not possible
	2. Handling (torque, probe stability, probe flexion)	Very good	Good	Bad	Very bad
Image quality	3. Two-dimensional echocardiography	Very good (good quality for all cardiac structures)	Good (satisfactory quality for cardiac structures of interest)	Bad (cardiac structures of interest difficult to analyse)	Very bad (no images)
	4. Colour Doppler				
	5. Pulsed Doppler				
	6. Continuous Doppler				

Results

Patients

A total of 38 children (median [range] age 9.3 years [7 days–12 years]; weight 12 [3.1–27] kg) underwent 75 TOE examinations using the micro-TOE probe. TOE indications, along with numbers of TOEs per patient, are shown in Table 2. Surgical procedures, mainly atrial or ventricular septal defect closures, are detailed in Table 2. During the study, no diagnosis changed after preoperative TOE compared with preoperative transthoracic echocardiography.

In the percutaneous procedures group, two patients underwent atrial septal defect closure (Fig. 1). One child underwent a balloon valvuloplasty of a severe mitral stenosis. One neonate (3 months, 6.9 kg) underwent a percutaneous dilatation of severe aortic valve stenosis. TOE (Fig. 2) was performed to guide the procedure and decrease the risk of aortic regurgitation. The balloon diameter was increased step-by-step from a balloon to aortic annulus ratio of 0.6. The gradient across the aortic valve was assessed after each balloon inflation. The procedure was stopped and successful with a maximal gradient < 25 mmHg without aortic regurgitation (Fig. 2D).

In the ICU group, TOEs were indicated for endocarditis in one child and in the aetiological investigation of stroke in two children. Three other children in the surgery group required TOE examinations postoperatively in the ICU because of poor quality transthoracic echocardiography imaging. Two were followed with repeated TOEs to assess cardiac function, cardiac haemodynamic parameters and aortic valve function under extracorporeal membrane oxygenation (ECMO) support (Fig. 3). One neonate in postoperative care for a total anomalous pulmonary venous return with an open breastbone required a TOE for a non-contributive transthoracic echocardiography to accurately evaluate cardiac function and pulmonary venous return (Fig. 4).

Ease of use

Detailed score results on insertion and handling by weight quartile are presented in Table 3. Insertion was rated as

‘very easy’ in all children apart from one, in whom insertion was ‘hard’. This 6-year old patient (14 kg) was in the ICU under ECMO support for low cardiac output syndrome after a mitral valve repair of a partial atrio-ventricular septal defect with severe mitral regurgitation. There was no significant difference between weight quartiles for the insertion score ($P=1.0$). Handling was significantly better in children in the lowest versus the other three weight quartiles ($P=0.001$). Repeated TOE examinations in patients under ECMO support were performed without any difficulty of insertion or handling.

Image quality

Images were generally of ‘good’ or ‘very good’ quality according to both operators (Table 3). Repeated TOE exams before and after surgery were rated similarly; and no difference in imaging quality between the beginning and end of the study was observed. Inter-rater agreements were significant for all the imaging quality criteria: two-dimensional (weighted kappa coefficient 0.27 ± 0.14 ; $P=0.026$), colour Doppler (0.26 ± 0.13 , $P=0.02$), pulsed Doppler (0.64 ± 0.19 ; $P=0.0004$) and continuous Doppler (0.30 ± 0.13 ; $P=0.001$). Weight, as a continuous variable, did not influence image quality for two-dimensional ($P=0.27$), pulsed Doppler ($P=0.54$) or continuous Doppler ($P=0.09$), but colour Doppler was rated better with lower weight ($P=0.007$).

When transoesophageal Doppler was used by the cardiac paediatric anaesthesiologist, TOE images were blurred, requiring transoesophageal Doppler transducer withdrawal to continue the examination. The use of electrocautery by the surgeon blurred the colour Doppler.

Total score

The mean \pm standard deviation (SD) total scores were best in children in the lowest weight quartile: 7.4 ± 1.6 for < 7 kg, 9.1 ± 2.4 for 7–11.9 kg, 10.3 ± 2.3 for 12–17 kg and 10.1 ± 1.9 for > 17 kg ($P=0.02$). Medians, interquartile and ranges are shown in Fig. 5.

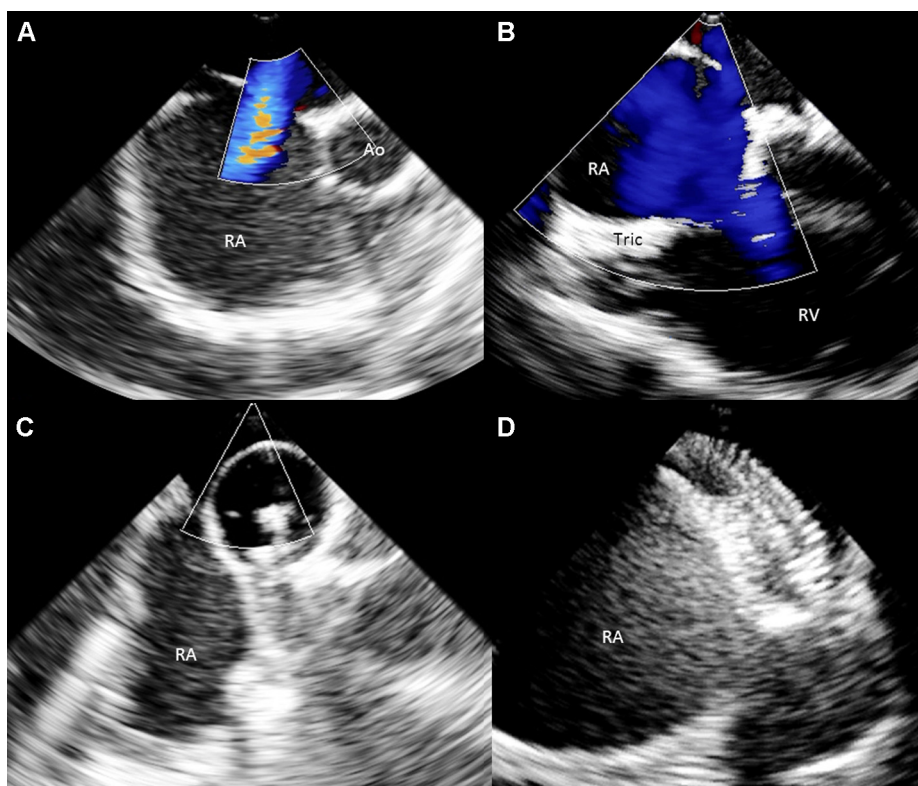


Figure 1. Intraoperative two-dimensional TOE in a child with an atrial septal defect. Mid oesophageal view (45°) with colour Doppler on the inter-atrial septum; an ostium secundum atrial septal defect is observed with a left to right shunt (A). Low oesophageal view (0°) of the right ventricle, which is enlarged; colour Doppler does not show tricuspid valve regurgitation (B). Mid oesophageal view of the inter-atrial septum during the balloon sizing of the atrial septal defect (C). Mid oesophageal view of the atrial septal defect occluder after release (D). Ao: aorta; RA: right atrium; RV: right ventricle; TOE: transoesophageal echocardiography; Tric: tricuspid valve.

Low-weight children

Six children (15.7%) weighed <5.5 kg and underwent TOE examinations for surgery of atrio-ventricular septal defects ($n=2$), ventricular septal defects ($n=2$), arterial switch ($n=1$) and total anomalous pulmonary venous return ($n=1$). Probe insertion was 'very easy' in all cases; handling was 'very good' in five cases and 'good' in the remaining case. Stability of the probe was better than in larger children ($P=0.001$). Imaging quality was at least 'good' in all cases. In the neonate with transposition of the great vessels, ECMO support was indicated immediately after the arterial switch, given a severe left heart dysfunction diagnosed on post-operative TOE combined with haemodynamic parameters. The neonate in postoperative care for a total anomalous pulmonary venous return had an open breastbone without any transthoracic echocardiography window. Despite an unstable haemodynamic status, probe insertion and TOE examination were well tolerated and accurate evaluation of cardiac function and pulmonary venous return was achieved (Fig. 4).

Safety

No complications of the TOE examinations were reported during the study. In the 6-year old patient under ECMO in whom probe insertion was 'hard', bradycardia and hypotension occurred during probe insertion. However,

haemodynamic stability recovered after a few minutes and the examination could be fully performed.

The smallest patient (3.1 kg) was examined for the post-operative course of total anomalous pulmonary venous return repair with open breastbone and haemodynamic instability. A second neonate (3.5 kg) with transposition of the great vessels had a severe left ventricular dysfunction following arterial switch, with open breastbone and ECMO. Insertion of the micro-TOE probe was performed blindly with a finger. Despite a precarious haemodynamic status, neither respiratory failure nor hemodynamic impact was observed in these cases.

Discussion

In this study, we have demonstrated that the new release of the micro-multiplane TOE probe S8-3t is easy to use, safe and provides good quality images, particularly in low-weight children. The good quality imaging allowed accurate postoperative assessment of CHD surgery, guidance of percutaneous CHD intervention and investigation of cardiac function and haemodynamic parameters in the ICU.

The first report of the original children's micro-multiplane TOE probe was published in 1999 by Shiota et al. [9]. Various reports have demonstrated its initial safety and usefulness [8, 11–14]. However, this former release was gradually phased out in our centre and others because of degradation of imaging quality during examinations due to

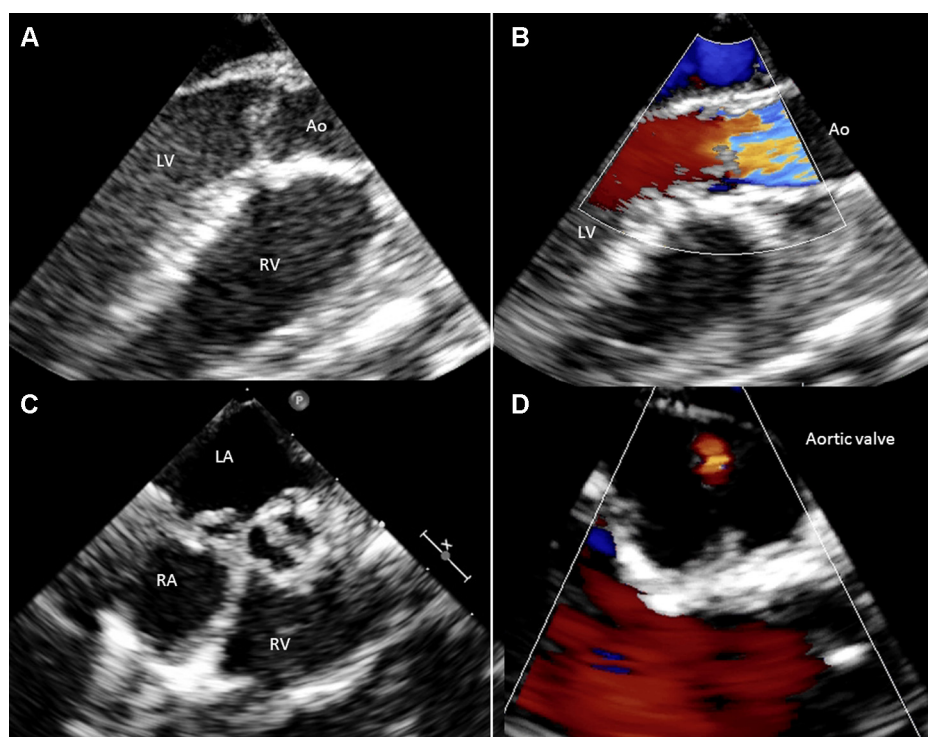


Figure 2. Intraoperative two-dimensional TOE in a neonate with severe bicuspid aortic valve stenosis. Mid oesophageal view (120°) of the left outflow tract; the aortic valve is thick (A). Mid oesophageal view (120°) of the left outflow tract with colour Doppler; an acceleration of blood flow on the aortic valve is observed (B). Mid oesophageal view (45°) of the aortic valve; the aortic valve is bicuspid (C). Mid oesophageal view (45°) of the aortic valve after the balloon valvuloplasty; the fusion of the commissure between the posterior and left-anterior cusp was opened with a small commissural aortic insufficiency (D). Ao: aorta; LA: left atrium; LV: left ventricle; RA: right atrium; RV: right ventricle; TOE: transoesophageal echocardiography.

an overheating phenomenon [10]. Given the lack of another dedicated probe for neonates, the AcuNav™ intracardiac echocardiographic intravascular ultrasound transducer single longitudinal plane (Siemens Medical Solutions, Mountain View, CA, USA) was used off-label as a TOE probe by some teams [15]. The new micro-multiplane TOE probe was designed to overcome these former issues. However, few reports are available that have assessed the safety and efficiency of the new release of the micro-multiplane TOE probe S8-3t [10,15].

Our study supports the use of this new probe in daily practice, particularly in neonates. Handling was significantly easier in the smallest patients. Pushparajah et al. described a necessary flexion of the probe in order to maintain good image quality in older children [10]. The larger oesophagus in older children may offer less stability to the thin micro-TOE probe than to larger TOE probes. However, they found that handling was good in neonates, for whom the micro-TOE probe was developed [10]. In our study, imaging was of good quality, and two-dimensional images had a good spatial and temporal resolution. The total score was better among low-weight children (< 7 kg). Standard TOE probes have been found to provide better imaging in larger patients, with easier handling [10,14]. The image quality in the far field is lower quality in larger patients because the centre frequency of the micro-multiplane TOE probe is 7.5 MHz, which gives an optimal image to a depth of 6–7 cm [14].

Our study provides further evidence of the impact of TOE for children undergoing cardiac surgery. Intraoperative

use was the most common indication for TOE in our paediatric cohort. TOE is recommended after cardiac surgery to assess the result before disconnection of the cannula and sternal closure [1]. In our small sample of patients, no residual lesions were observed that required complementary intervention. However, in a 3.5-kg neonate with transposition of the great vessels, micro-TOE after the arterial switch diagnosed severe left ventricular dysfunction and ECMO was required. Thus, TOE was useful to assess cardiac de-airing, ventricular function after the bypass period and haemodynamic status, thereby guiding fluid management, inotropic therapy and ECMO indication [7]. Postoperative TOE is advocated because patients who leave the operating room with a residual defect have a higher incidence of reoperation and death in the immediate postoperative period compared with those whose problems are addressed [16]. Bettex et al. have reported that 865 postoperative TOE examinations had a surgical impact in 12.7% of patients; and indicated a second bypass run in 7.3% of children [17]. When surgical revision was performed, TOE findings were confirmed in all cases, demonstrating the efficiency of TOE [17].

The sensitivity of TOE to detect residual ventricular septal defect is good [18,19]. In tetralogy of Fallot repair, intraoperative echocardiography helps in differentiating 'fixed' from 'dynamic' obstruction and helps obviate needless revisions [20]. Furthermore, Bettex et al. demonstrated that the impact of TOE was higher in neonatal surgery [17]. We also observed that micro-TOE is particularly useful

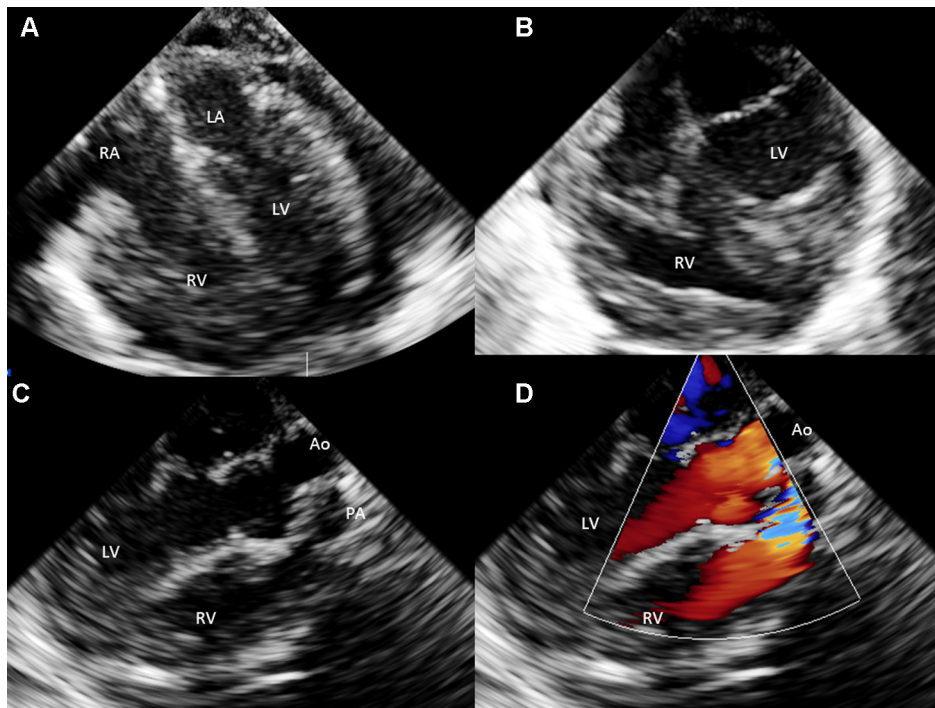


Figure 3. TOE in a neonate with D transposition of the great vessels in postoperative care of the arterial switch, with an open breastbone and ECMO. Mid oesophageal four-chamber view in diastole (A). Mid oesophageal four-chamber view in systole (B). Mid oesophageal two-dimensional view (120°) of the left outflow tract; anastomosis of the great vessels is observed with a mild discongruence (C). Mid oesophageal two-dimensional view (120°) of the left outflow tract with colour Doppler; a mild acceleration of blood flow on the pulmonary outflow tract is observed (D). Ao: aorta; ECMO: extracorporeal membrane oxygenation; LA: left atrium; LV: left ventricle; RA: right atrium; RV: right ventricle; PA: pulmonary artery; TOE: transoesophageal echocardiography.

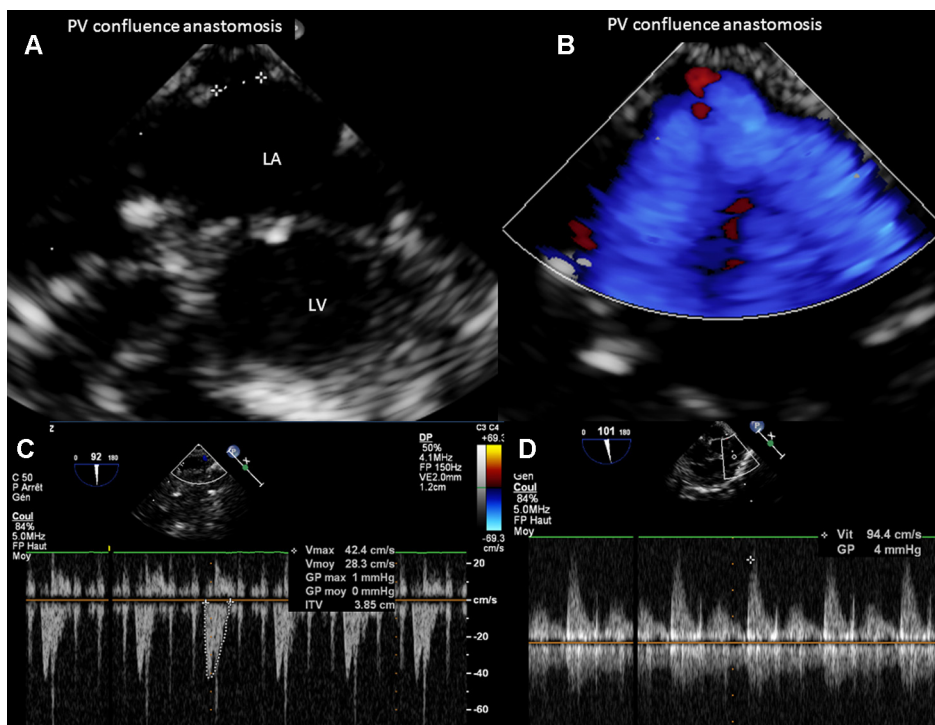


Figure 4. TOE in a neonate in postoperative care for a total anomalous pulmonary venous return with an open breastbone and high frequency ventilation. Pulmonary venous return confluence anastomosis to the posterior wall of the left atrium (A). Colour Doppler without aliasing on pulmonary venous return confluence anastomosis to the posterior wall of the left atrium (B). Pulsed Doppler on pulmonary venous return confluence anastomosis (C). Continuous Doppler on the pulmonary outflow tract (D). LA: left atrium; LV: left ventricle; PV: pulmonary vein; TOE: transoesophageal echocardiography.

Table 2 Indications for the transoesophageal echocardiography (TOE) examinations.

	TOE examinations (n = 75)
TOE indications	
Before cardiac surgery to confirm lesions	30 (40.0)
After cardiac surgery to assess the result	31 (41.3)
To guide percutaneous procedures	4 (5.3)
To assess cardiac function in the ICU	10 (13.3)
Surgeries	
Atrial septal defect closure	9 (12.0)
Ventricular septal defect closure	8 (10.7)
Tetralogy of Fallot repair	4 (5.3)
Right ventricular outflow tract reconstructions ^a	2 (2.7)
Atrio-ventricular septal defect repair	2 (2.7)
Total cavo-pulmonary derivation	2 (2.7)
Other ^b	4 (5.3)
Percutaneous procedures	
Atrial septal defect closure	2 (2.7)
Balloon valvuloplasty of a severe mitral stenosis	1 (1.3)
Percutaneous dilatation of severe aortic valve stenosis	1 (1.3)
ICU	
Endocarditis	1 (1.3)
Aetiological investigation of stroke	2 (2.7)
Post-cardiac surgery due to poor quality transthoracic echocardiography	7 (9.3)
Number of examinations per patient	
1	7 (18.4)
2	27 (71.1)
3	3 (7.9)
5	1 (2.6)

^a In children with common truncus arteriosus and pulmonary atresia with ventricular septal defect.

^b One each of: modified Konno operation, aortic valve commissurotomy, arterial switch and total anomalous pulmonary venous return repair.

during the postoperative care of neonatal patients, particularly when there is an open breastbone or ECMO support. Furthermore, ECMO withdrawal indication is reinforced by TOE findings.

Performing TOE systematically before surgery is more controversial. In our cohort, TOE before surgery did not provide additional data over transthoracic echocardiograph.

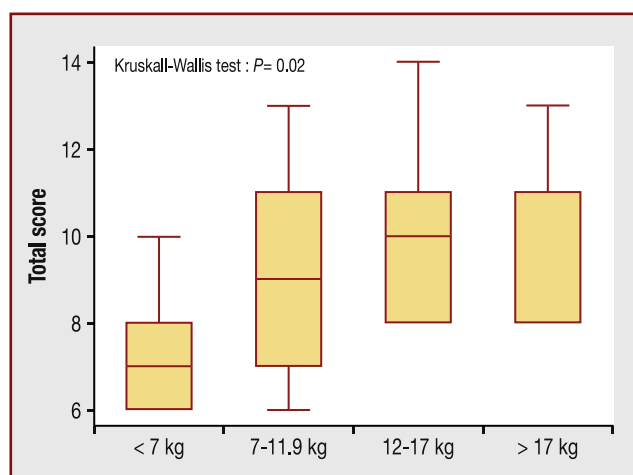


Figure 5. Total score by weight quartile (Kruskal-Wallis test). Lines show medians; boxes show interquartile; whiskers show range.

Transthoracic examination is usually sufficient in children to provide a detailed preoperative assessment of the lesions. Major undiagnosed findings have been estimated to be found in < 0.5% of patients [21].

Some studies have assessed the efficiency of micro-TOE during perioperative care for patients undergoing cardiac surgery using different miniaturized probes [10,13,15,22]. We provide further evidence of the impact of TOE for children undergoing cardiac catheterization. A neonate with severe aortic stenosis underwent successful percutaneous dilation under TOE guidance. TOE allowed a step-by-step dilation procedure with closed assessment of aortic valve gradient and continence. The procedure was successful and TOE guidance avoided unnecessary oversized dilation and subsequent risk of aortic insufficiency [23]. Echo-guidance also allows lower fluoroscopy time and lower contrast load [23]. Furthermore, this case illustrates how the cardiovascular imaging specialists and interventionalists can work together effectively to plan and execute catheter interventions for congenital heart disease [2].

Currently, the micro-TOE probe does not incorporate three-dimensional technology. However, three-dimensional echocardiography seems to be better for measuring aortic valve annulus before balloon valvuloplasty [24,25]. We used the micro-TOE probe in two children weighing < 20 kg, for whom the use of the three-dimensional TOE probe is not recommended, to guide percutaneous closure of atrial septal defects. Interventions were successful, but three-dimensional echocardiography is useful in these cases to assess the shape of the atrial septal defect [26].

Our study has some limitations. First, it only involved 38 children. However, children of different weights with wide indications for TOE were included, allowing assessment of the new release of the micro-TOE probe in various settings. Second, it only lasted 3 months, thus the reliability over time remains to be demonstrated. However, 75 examinations were performed without any change in image quality. This assertion remains true at the time of submission of this paper.

Table 3 Insertion, handling and image quality results.

Score	Insertion	Handling	2-dimensional	Colour	Pulsed	Continuous
< 7 kg (n = 9 [23.7%])						
1	9 (100)	5 (55.6)	5 (55.6)	9 (100)	7 (77.7)	8 (88.9)
2	—	4 (44.4)	4 (44.4)	—	—	1 (11.1)
3	—	—	—	—	2 (22.2)	—
4	—	—	—	—	—	—
7–11.9 kg (n = 10 [26.3%])						
1	10 (100)	1 (10.0)	5 (50.0)	7 (70.0)	4 (40.0)	5 (50.0)
2	—	7 (70.0)	4 (40.0)	3 (30.0)	6 (60.0)	5 (50.0)
3	—	2 (20.0)	1 (10.0)	—	—	—
4	—	—	—	—	—	—
12–17 kg (n = 10 [26.3%])						
1	9 (90.0)	—	3 (30.0)	6 (60.0)	5 (50.0)	6 (60.0)
2	—	3 (30.0)	6 (60.0)	4 (40.0)	3 (30.0)	4 (40.0)
3	1 (10.0)	6 (60.0)	1 (10.0)	—	2 (20.0)	—
4	—	1 (10.0)	—	—	—	—
> 17 kg (n = 9 [23.7%])						
1	9 (100)	—	3 (33.3)	4 (44.4)	5 (55.6)	4 (44.4)
2	—	4 (44.4)	5 (55.6)	5 (55.6)	3 (33.3)	5 (55.6)
3	—	4 (44.4)	1 (11.1)	—	1 (11.1)	—
4	—	1 (11.1)	—	—	—	—
<i>P</i> ^a	1.0	0.006	0.91	0.07	0.12	0.23

^a Exact Fischer test was used to assess the relationship between each echographic parameter and the weight quartiles.

Conclusions

This study suggests that the micro-multiplane TOE is safe and efficient for use in neonates and children. This minimally invasive tool may increase the impact of TOE in paediatric cardiology.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.acvd.2014.05.001>.

References

- [1] Ayres NA, Miller-Hance W, Fyfe DA, et al. Indications and guidelines for performance of transesophageal echocardiography in the patient with pediatric acquired or congenital heart disease: report from the task force of the Pediatric Council of the American Society of Echocardiography. *J Am Soc Echocardiogr* 2005;18:91–8.
- [2] Kutty S, Delaney JW, Latson LA, Danford DA. Can we talk? Reflections on effective communication between imager and interventionalist in congenital heart disease. *J Am Soc Echocardiogr* 2013;26:813–27.
- [3] Russell IM, Silverman NH, Miller-Hance W, et al. Intraoperative transesophageal echocardiography for infants and children undergoing congenital heart surgery: the role of the anesthesiologist. *J Am Soc Echocardiogr* 1999;12:1009–14.
- [4] Bezold LI, Pignatelli R, Altman CA, et al. Intraoperative transesophageal echocardiography in congenital heart surgery. The Texas Children's Hospital experience. *Tex Heart Inst J* 1996;23:108–15.
- [5] Randolph GR, Hagler DJ, Connolly HM, et al. Intraoperative transesophageal echocardiography during surgery for congenital heart defects. *J Thorac Cardiovasc Surg* 2002;124:1176–82.
- [6] Sutherland GR, Stumper OF. Transthoracic versus transesophageal echocardiography in the pediatric patient. *Curr Opin Pediatr* 1993;5:598–605.
- [7] Kamra K, Russell I, Miller-Hance WC. Role of transesophageal echocardiography in the management of pediatric patients with congenital heart disease. *Paediatr Anaesth* 2011;21:479–93.
- [8] Wolfe LT, Rossi A, Ritter SB. Transesophageal echocardiography in infants and children: use and importance in the cardiac intensive care unit. *J Am Soc Echocardiogr* 1993;6:286–9.
- [9] Shiota T, Lewandowski R, Piel JE, et al. Micromultiplane transesophageal echocardiographic probe for intraoperative study of congenital heart disease repair in neonates, infants, children, and adults. *Am J Cardiol* 1999;83:292–5 [A7].
- [10] Pushparajah K, Miller OI, Rawlins D, Barlow A, Nugent K, Simpson JM. Clinical application of a micro multiplane transoesophageal probe in congenital cardiac disease. *Cardiol Young* 2012;22:170–7.
- [11] Motta P, Miller-Hance WC. Transesophageal echocardiography in tetralogy of Fallot. *Semin Cardiothorac Vasc Anesth* 2012;16:70–87.

- [12] Zyblewski SC, Shirali GS, Forbus GA, et al. Initial experience with a miniaturized multiplane transesophageal probe in small infants undergoing cardiac operations. *Ann Thorac Surg* 2010;89:1990–4.
- [13] Scohy TV, Gommers D, Jan ten Harkel AD, Deryck Y, McGhie J, Bogers AJ. Intraoperative evaluation of micromultiplane transesophageal echocardiographic probe in surgery for congenital heart disease. *Eur J Echocardiogr* 2007;8:241–6.
- [14] Scohy TV, Gommers D, Schepp MN, McGhie J, de Jong N, Bogers AJ. Image quality using a micromultiplane transesophageal echocardiographic probe in older children during cardiac surgery. *Eur J Anaesthesiol* 2009;26:445–7.
- [15] Ferns S, Komarlu R, Van Bergen A, Multani K, Cui VW, Robertson DA. Transesophageal echocardiography in critically ill acute postoperative infants: comparison of AcuNav intracardiac echocardiographic and microTEE miniaturized transducers. *J Am Soc Echocardiogr* 2012;25:874–81.
- [16] Ungerleider RM. The use of intraoperative echocardiography with Doppler color flow imaging in the repair of congenital heart defects. *Echocardiography* 1990;7:289–304.
- [17] Bettex DA, Schmidlin D, Bernath MA, et al. Intraoperative transesophageal echocardiography in pediatric congenital cardiac surgery: a two-center observational study. *Anesth Analg* 2003;97:1275–82.
- [18] Yang SG, Novello R, Nicolson S, et al. Evaluation of ventricular septal defect repair using intraoperative transesophageal echocardiography: frequency and significance of residual defects in infants and children. *Echocardiography* 2000;17:681–4.
- [19] Hanna BM, El-Hewala AA, Gruber PJ, Gaynor JW, Spray TL, Selim MA. Predictive value of intraoperative diagnosis of residual ventricular septal defects by transesophageal echocardiography. *Ann Thorac Surg* 2010;89:1233–7.
- [20] Kaushal SK, Radhakrishnan S, Dagar KS, et al. Significant intraoperative right ventricular outflow gradients after repair for tetralogy of Fallot: to revise or not to revise? *Ann Thorac Surg* 1999;68:1705–12 [discussion 12–3].
- [21] Sheil ML, Baines DB. Intraoperative transoesophageal echocardiography for paediatric cardiac surgery—an audit of 200 cases. *Anaesth Intensive Care* 1999;27:591–5.
- [22] Sloth E, Hasenkam JM, Sorensen KE, et al. Pediatric multiplane transesophageal echocardiography in congenital heart disease: new possibilities with a miniaturized probe. *J Am Soc Echocardiogr* 1996;9:622–8.
- [23] Bourgault C, Rodes-Cabau J, Cote JM, et al. Usefulness of Doppler echocardiography guidance during balloon aortic valvuloplasty for the treatment of congenital aortic stenosis. *Int J Cardiol* 2008;128:30–7.
- [24] Martin R, Hascoët S, Dulac Y, et al. Comparison of two- and three-dimensional transthoracic echocardiography for measurement of aortic annulus diameter in children. *Arch Cardiovasc Dis* 2013;106:492–500.
- [25] Black D, Ahmad Z, Lim Z, Salmon A, Veltdman G, Vettukattil J. The accuracy of three-dimensional echocardiography with multiplanar reformatting in the assessment of the aortic valve annulus prior to percutaneous balloon aortic valvuloplasty in congenital heart disease. *J Invasive Cardiol* 2012;24:594–8.
- [26] Abdel-Massih T, Dulac Y, Taktak A, et al. Assessment of atrial septal defect size with 3D-transesophageal echocardiography: comparison with balloon method. *Echocardiography* 2005;22:121–7.